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Estimating Optimal Conservation in Agricultural Landscapes when Costs and Benefits of Conservation Measures are Heterogeneous in Space and over Time

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Abstract:

Designing agri-environmental schemes targeted at conservation poses the key question of how many financial resources should be allocated to address a particular aim such as the conservation of an endangered species. Economists can contribute to an answer by estimating the ‘optimal level of species conservation’. This requires an assessment of the supply and the demand curve for conservation and a comparison of the two curves to identify the optimal conservation level. In a case study we estimate the optimal conservation level of Large Blue butterflies (protected by the EU Habitats Directive) in the region of Landau, Germany. The difference to other studies estimating optimal conservation is that a problem is addressed where costs and benefits of conservation measures are heterogeneous in space and over time. In our case study we find a corner solution where the highest proposed level of butterfly conservation is optimal. Although our results are specific to the area and species studied, the methodology is generally applicable to estimate how many financial resources should be allocated to conserve an endangered species in the context of agri-environmental schemes.

Key words: agri-environmental policy, biodiversity, optimal conservation, spatial heterogeneity, willingness-to-pay

1. Introduction

In the past, European agricultural landscapes were influenced by a great variety of land-use and farming systems, which provided a broad habitat and species diversity. This changed over the last sixty years or so; intensive fertiliser and pesticide use, irrigation and drainage to achieve homogeneous water levels best suited for production, and the destruction of natural and man-made landscape structures such as wet sinks, hedges and stone walls have resulted in the loss of many habitats. Additionally, farming is often no longer economically viable in areas with small and extensive farming systems where livestock rearing and traditional cultivation methods created semi-natural habitats that support a wide range of species (MacDonald *et al*., 2000). The problems of land abandonment and agricultural intensification are now seen as two main causes of farmland biodiversity losses (Baldock *et al*., 1996; Bignal and McCracken, 2000; Benton *et al*., 2003).

In order to reverse the trend of biodiversity loss in European agricultural landscapes agri-environmental schemes have been developed, compensating farmers for farming in a conservation-friendly manner. Agri-environmental schemes were set up all over the EU following Regulations 2078/92 and 1257/99, which despite giving some general guidelines, left the details of payments up to the individual Member States. Today, several billion Euros are spent on such programmes in Europe each year (European Commission, 2005).

Designing agri-environmental schemes on the national or regional level leads to the key question of how many financial resources should be allocated to address a particular conservation aim, e.g., the conservation of an endangered species. Economists can contribute to answering this question by estimating the 'optimal level of species conservation'. On a *conceptual* level this is straightforward. Similar to assessing the optimal production of any other good it requires estimating the supply and demand curve for the good 'species conservation' and then estimating the intersection between the two curves, with the intersection point showing the optimal level of species conservation. In case of a corner solution where the two curves do not intersect in the range of feasible conservation levels it is either optimal to have no conservation at all – if the supply curve lies above the demand curve – or to have as much conservation as feasible – if the demand curve lies above the supply curve.

Following the described conceptual approach, the aim of this paper is to *empirically* estimate the demand and supply curve for the conservation of an endangered species and the optimal level of species conservation. As an example we use the conservation of the endangered

Scarce Large Blue butterfly (*Maculinea teleius*, protected by the EU Habitats Directive) in the region of Landau, Germany. The butterfly relies on open meadows and its survival depends on the time and sequence of mowing. Costs for conservation arise because butterfly-friendly mowing regimes differ from the profit maximising mowing regime of farmers.

To estimate the demand curve for the public good 'butterfly conservation' we carried out a survey in the municipality of Landau, and asked residents about their willingness-to-pay for the conservation of the endangered butterfly. For the estimation of the supply curve we take the existing EU-policy framework with agri-environmental schemes as given. We assume that farmers are compensated for butterfly-friendly mowing through an agri-environmental scheme, and consider the amount of compensation plus administrative costs that arise for the regulator as conservation costs. The costs of mowing and its effect on the butterfly population are heterogeneous in space and over time, i.e., they depend on where a particular meadow is located as well as when and how often a meadow is mown. To estimate the supply curve it is necessary to identify the cost-effective mowing regime, i.e., the mowing regime which provides butterfly conservation at least costs. For this purpose we apply an ecological-economic modelling procedure that has been developed by Drechsler *et al*. (2005) to estimate cost-effective compensation payments for species conservation measures.

We only found few studies that empirically estimate the optimal level of conservation in agricultural (e.g. Macmillan *et al*., 2004) and other landscapes (e.g. Siikamäki and Layton, 2005). The novelty of our study is that we address a conservation problem where costs and benefits of individual conservation measures are heterogeneous in space and over time. Although our case study results are specific to the area and species studied, the methodology is generally applicable to estimate how many financial resources should be allocated to conserve an endangered species in the context of agri-environmental schemes when heterogeneity matters. Recent research has emphasized the importance of spatial (e.g. Bockstael, 1996; Babcock *et al*., 1997; Wätzold and Drechsler, 2005) and temporal heterogeneity (e.g. Drechsler and Wätzold, in press) when designing conservation measures. The challenge of addressing heterogeneity lies in estimating the supply curve which requires the identification of the least cost conservation option for every conservation level. This may be difficult, as in order to achieve a certain conservation level in a region a number of individual conservation measures have to be allocated in space and time. Usually the costs of the measures and also their ecological benefits depend on where and when the measures are carried out. These spatial and temporal heterogeneities easily lead to non-trivial optimisation problems in finding the combinations of individual measures that provide conservation at least costs (see Wossink et al. (1999), Polasky et al. (2001), Johst et al. (2002) and Lichtenstein and Montgomery (2003) as examples for this type of research).

In the following Section we briefly introduce the conservation problem and the case study area. Section Three and Section Four describe how the costs and the benefits for butterfly conservation are estimated. By deriving the supply and demand curve the optimal level of conservation is estimated in Section Five. The results are summarised and discussed in the final Section.

2. Conservation problem and study area

2.1 Ecology of the butterfly and its dependence on mowing

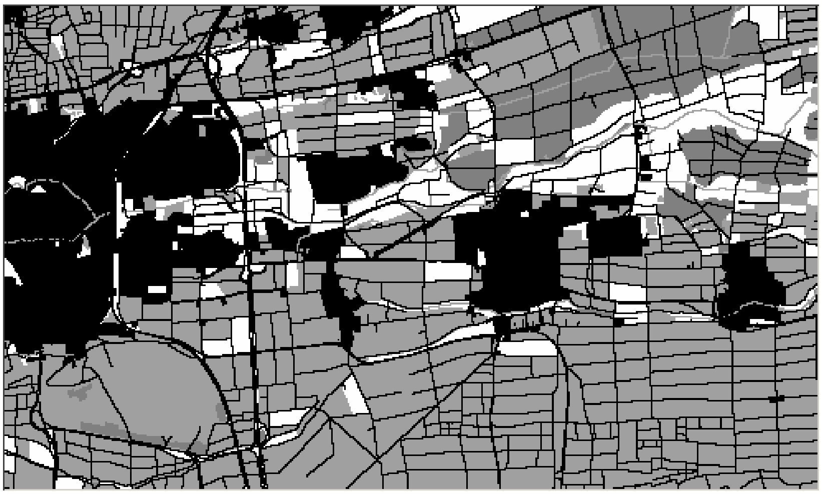
The Scarce Large Blue, *Maculinea teleius*, is a highly endangered butterfly, listed in many Red Data Books (e.g. Pretscher *et al*., 1998; Van Swaay and Warren, 1999) and in Annexes II and IV of the EU Habitats Directive. *M. teleius* is a meadow-dwelling butterfly that relies on the presence of open landscapes. Most adults fly in July and early August. Females lay their eggs on the plant Large Pimpernel (*Sanguisorba officinalis*). The caterpillars leave this host plant after 3 weeks by falling on the ground. They are carried by red ants (certain *Myrmica* species) into their nest where they are fed by the ants over winter (Thomas and Settele, 2004). Both plant and ant species can only survive on meadows that are mown at certain times and frequencies.

Until the 1950s *M. teleius* was quite common in Germany, which is largely explained by the dependence on a certain mowing regime. Until today, however, its populations and distribution have experienced severe declines. In the past not all meadows of a region were synchronously mown, leading to a mowing season that lasted throughout the entire summer. Therefore, even if at a particular time some meadows did not suit the butterflies, a sufficient number of other meadows remained suitable which could be reached by butterflies through dispersal. Nowadays, however, due to the development of machines all meadows in a region are typically mown within a very short time twice a year (or even more often), with the first cut usually taking place at the end of May and a second cut six to eight weeks later. This mowing regime (which we refer to as the ‘conventional mowing regime’), however, creates difficulties for the butterflies’ reproduction, especially since the second cut falls exactly into the time window when the butterflies deposit eggs on the Sanguisorba plants.

2.2 Study region and ecological situation

The study was conducted in a region around the town of Landau (Rhineland-Palatinate, SW-Germany) in the Upper Rhine Valley. The landscape is characterised by a mixture of arable land (including vine yards), forests, meadows and settlements. Figure 1 shows a typical landscape of the study region. The meadow cover in the area is approximately 10-20%.

Figure 1: Typical landscape from the study region



The dimension of the area depicted on the map is 10x6 km^2. (black: settlement/roads; dark grey: forest; light grey: open land, water bodies; white: meadows).
Source: Drechsler *et al*. (2005)

As with the whole of Germany, the Scarce Large Blue has become rather rare in the study region. During a long-term observation study in the region, which started in 1989, merely few individuals were detected each year (Settele, 1996 and 2005). This is a strong indication for extremely low population sizes. For non-specialist observers this means that the chances of seeing the butterfly are very low. Previously the species could have been observed much more frequently (DeLattin *et al*., 1957; Kraus, 1993).

2.3 Definition of conservation levels

These rare observation events form the baseline for our study. If population sizes are increased with the introduction of adequate mowing regimes, the chance that people living in the area will see *M. teleius* increases and the risk of extinction decreases. For many butterflies which are ecologically similar to our study species, one only comes across 10 to 20 individuals per day, even if 500-1000 individuals/ha are present over the entire flight season (Kockelke *et al*, 1994; Nowicki *et al*., 2005). Thus, even if in our case the population size is increased 200fold, the normal landscape visitor might only sporadically see the butterfly. Further conservation measures will increase the visibility of the butterfly and contribute to the reduction of the extinction probability. For the survey implemented to elicit people's willingness to pay for different conservation schemes (see Section 4), we differentiated three levels of conservation as indicated in Table 1.

Table 1: Three levels of conservation

	Conservation level 1	**Conservation level 2**	**Conservation level 3**
Estimated change in population size from currently ca. 10 individuals to	2 000	8 000	32 000
Size of conservation area (ha)	4	16	64
Visibility	sporadic	occasional	often
Estimated change in extinction risk	slightly reduced	considerably reduced	seriously reduced

The upper limit of 64 ha represents approximately 8% of the overall meadow area of 794 ha in the area where we consider conservation measures. The limit was chosen because it is large enough to lead to a situation which is satisfactory from a conservation point of view. On the other hand, it is small enough not to significantly affect the (potential) use of the meadow area for alternative purposes including conservation of other species such as meadow birds.

3. Estimating the costs of conservation

To estimate the supply curve the aggregated and marginal costs for the various conservation levels need to be estimated. This involves the identification of cost-effective mowing regime(s) and their effect on the butterfly population. For this purpose, we apply an ecological-economic modelling approach developed by Johst *et al*. (2002) and Drechsler *et al*. (2005). The approach has been designed to identify cost-effective compensation payments for measures to preserve endangered species. In the following we briefly describe the basic structure of the approach and refer, for a more detailed explanation, to Drechsler *et al*. (2005) who apply the approach to the conservation problem of this study.

The ecological-economic modelling approach consists of three components: (I) An economic model to determine the costs of alternative mowing regimes for each meadow in the study region as well as the overall costs and the compensation payments necessary to induce land users to adopt these mowing regimes, (II) an ecological model to determine the ecological effects of the alternative mowing regimes on the butterfly population, and (III) an optimisation component where the results of the ecological and economic model are integrated to identify the cost-effective mowing regimes and the corresponding compensation payments. We estimate the costs for implementing various mowing regimes in the area east of Landau (the area shown in Figure 1). This area consists of potentially suitable meadows which have been occupied by decreasing numbers of *M. teleius* and are habitat for closely related species, indicating a principle suitability of the habitat.

3.1 Economic model

In the economic model it is assumed that compensation payments necessary to induce farmers to adopt a particular mowing regime are determined by three factors. The first factor is compensation for the foregone profit that arises because the farmers cannot carry out the profit maximising mowing regime. This compensation is determined for all 112 alternative mowing regimes for all meadows in the region by using the method of standard gross margin calculations. We only give a brief summary of how the field specific compensations have been calculated, a detailed description can be found in Bergmann (2004).

In the study region, grassland is used intensively in dairy and cattle production. Farmers harvest silage or hay with a first cut approximately at the end of May, a second cut about six weeks later and – sometimes – a third cut in August or September. The energy content is the most important factor that determines the silage’s and hay’s quality and it is maximised by the prevalent mowing regime. Therefore, the reduction in energy yields per hectare that is caused by the different mowing regimes compared to the prevalent mowing regime forms the basis of the calculations of the compensation for the foregone profits.

The reduction in energy yields associated with the various mowing regimes were estimated based on information about medium grassland yields in the region. We take into account for each meadow soil quality and soil humidity, which have a positive influence on productivity, and altitude, which has a negative influence. Furthermore, costs for transport, machinery and fertiliser required for the various mowing regimes are considered. As part of these costs (calculated on a per hectare basis) decrease with an increase in meadow size we take meadow size into account, as well. The necessary compensation for the foregone profit is then calculated for each mowing regime and each meadow.

The second factor that determines the compensation payments for butterfly-friendly mowing regimes are the different types of transaction costs that farmers face if they participate in a compensation payment scheme. Farmers have to gather information about the scheme, fill out administrative documents and spend some time with administrative officers in case their compliance with the scheme's requirements is monitored. In order to create sufficient incentives for participating in butterfly-friendly mowing regimes, farmers need to be compensated for transaction costs. The compensation was estimated to amount 100€/ha per year.

For the estimation of compensation for farmers a third factor has to be taken into account: the decision to participate in a conservation programme depends on the farmer's attitude towards conservation (which differs among farmers). Furthermore, due to different characteristics of individual farms such as machinery, farm size, and experience of the farmer with conservation programmes, administrative costs as well as costs for conservation measures differ among farmers, too. To take these differences into account a variable u is introduced, where a positive (negative) u indicates that the effect of attitude towards conservation and farm characteristics require lower (higher) than average payments to induce a farmer to join the conservation programme. As it is difficult to get information about the distribution of u, we assume that for each meadow u is a uniform random variable $u \in [-u_0, +u_0]$ with a value for u_0 of 50€.

Overall, the compensation necessary to induce a farmer to mow a particular meadow according to a certain mowing regime are determined by the compensation for foregone profit and for administrative costs to participate in the programme. The compensation is then modified by a certain amount that reflects farm characteristics and the attitude of farmers towards conservation. We make the assumption that a farmer participates in the programme when the payments cover (at least) the participation costs. Regarding the design of agri-environmental programmes in Europe farmers are paid either according to individual costs or they all receive the same payment for a particular measure. Following the practise of most German agri-environmental programmes, we assume that all farmers in the study region receive the same compensation for applying a certain mowing regime. As costs differ among farmers, this implies that farmers with costs lower than the payment receive a producer surplus amounting to the payment minus the individual conservation cost.

3.2 Ecological model

An ecological simulation model is used to determine the effects of the various mowing regimes on the butterfly population. Mowing affects the survival of the butterflies in a direct and indirect way. The direct effect is that mowing leads to a cut of *Sanguisorba* plants and that larvae and eggs on plants are destroyed. Furthermore, egg deposition on the plant is only possible after the plant has re-grown after a four week period. Indirect effects arise because the frequency of mowing determines the abundance of *Sanguisorba* plants and ant nests. Without mowing there would be succession and the *Sanguisorba* plants would disappear, hence, fallow meadows are not suitable for *M. teleius*. Furthermore, the frequency of mowing has an influence on the appearance of the host ant where too short as well as too long mowing intervals are harmful for the ants. To estimate the effect of mowing the ecological model simulates the life cycle of the butterfly and how it is influenced by the direct and indirect effects (a detailed description of the model can be found in Johst *et al*., 2006).

The life cycle of the butterfly is simulated for every meadow in the region. The resulting dynamics of the butterfly population are influenced by an exchange of individual butterflies between meadows during the flight period. In order to integrate the dispersal of butterflies into the model it is assumed that the butterflies deposit their eggs with a certain probability on another than their 'home' meadow. Furthermore, the model takes into account that the movement from one meadow to another includes the possibility of dying during the flight. This possibility depends on the distance and the type of area (building, forest, meadow) between meadows. Through this movement meadows where the butterfly got extinct can be recolonised.

3.3 Identification of cost-effective mowing regime and cost calculations

The data generated with the economic and the ecological model allows to identify the cost-effective mowing regime and the payments necessary to induce farmers to apply this mowing regime for every available budget. For this purpose, in a first step we determine for a certain budget which meadows participate in the programme for one of the 112 mowing regimes. The choice of meadows is determined by the results of the economic model. First, the meadow whose programme participation requires the lowest payments is chosen for programme participation, then the meadow with the second lowest payment, and so on, until no more money is available in the budget to finance the participation of another meadow. For this calculation, one needs to bear in mind that all farmers receive the same payment. This implies that for every additional meadow whose participation requires higher payments, payments for all other meadows have to be higher, too.

For the resulting meadow area, the ecological model simulates the butterfly population dynamics for 20 years and the final total meadow area containing butterflies is recorded. To account for the randomness in the incentive component *u* of the costs and the randomness in the butterfly population dynamics, the whole analysis is repeated 100 times and an average, the expected meadow area occupied by butterflies, is taken. For each budget level, the expected area of meadow occupied is determined for all 112 promoted mowing regimes. Comparison of the results allows the most cost-effective mowing regime(s) to be identified for each budget.

To calculate the costs of the agri-environmental scheme to conserve the butterfly we have to take into account administrative costs that arise for the regulator as well. We take results from an empirical study by Falconer and Whitby (1999) on administrative costs of agri-environmental schemes in eight EU-countries, including Germany, and estimate administrative costs to be 10,20€ for each hectare land that is enrolled in the scheme (Falconer and Whitby, 1999: 73).

Figure 2: Costs for a certain area of meadows occupied by butterflies.

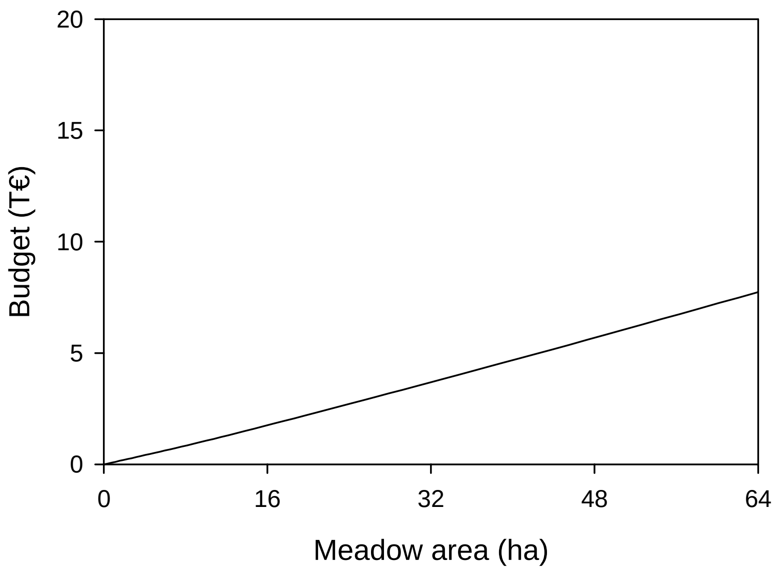


Figure 2 shows the costs to mow a certain meadow area in a butterfly-friendly manner for one of the most cost-effective mowing regimes, which is to mow twice a year: in the third weeks of May and June respectively. Payments for this mowing regime are low, as it is identical to the generally applied conventional mowing regime in the region except that the second cut is two weeks earlier than in the conventional scheme. Profit losses are therefore limited, especially if one considers that June is a busy time for farmers where they may not have the time to mow all their meadows synchronically. Altogether, for meadow areas *A* the required budget is approximately given by B = A∗123€/ha.

4. Estimating the demand for conservation

Demand was estimated by eliciting people's WTP for *M. teleius* conservation using Contingent Valuation (CV). This approach was chosen for two reasons: Firstly, it is capable of eliciting *ex ante* values. Secondly, CV covers the entire range of non-market economic values (Mitchell and Carson, 1989). This is important because the benefits associated with butterfly conservation are to a large extent composed of non-use values, which means that many people value *M. teleius* even though they are unlikely to ever see one. For the construction of the demand curve it was essential to estimate WTP for at least three levels of conservation (cf. Table 1).

4.1 Design of the study

Considerable effort was spent on designing the CV survey in a way that enables people to assimilate sufficient information on *M. teleius* and to value three different levels of butterfly conservation in terms of their WTP. The butterfly was described in a 10 page long information folder using literary descriptions, maps and pictures. As opposed to estimating the cost side of *M. teleius* conservation, which is merely based on the meadow area occupied by *M. teleius*, more attributes are needed to help participants distinguish between and value three different project sizes in terms of benefits received. Focus groups and a pilot study revealed that people require information on the number of butterflies that would occupy the conservation area, change in risk of extinction, and visibility of the species. An attempt was made to list the major impacts in a way that is easily comprehensible, although this sometimes involved making assumptions and simplifications (cf. Table 1).

The hypothetical market in which people were given the opportunity to engage in a monetary transaction that reflect their preferences for the three conservation projects was designed in a way that would reflect respondents' perceived property rights. An investigation of perceived property rights is important so that the credibility of the hypothetical market is enhanced (Garrod and Willis, 1999). Focus group discussions suggested that participants felt that they do not hold rights to conservation projects and therefore would be willing to pay to obtain the benefits associated with each conservation project. WTP to obtain an increase in the butterfly population therefore seems to be the correct welfare measure (compensating surplus) to be used in this study. According to pre-survey investigations, a plausible and credible payment method was identified to be donations into a specially created '*Maculinea* fund'. A payment card consisting of eight donation levels ranging from € 1 to € 160 was used to elicit households' maximum WTP per year over a five year period.

In order to estimate WTP it was decided to use a group-based approach to Contingent Valuation, called Market Stall (MS). The MS has been previously applied to value complex and unfamiliar wildlife projects (MacMillan, *et al.*, 2006; Lienhoop and MacMillan, 2006). The approach involves a group meeting lasting approximately 1.5 - 2 hours with up to 12 participants, with a follow-up telephone call after a week to obtain a final WTP estimate. During the meeting a moderator conveys relevant information on the environmental issue, the hypothetical market and the payment vehicle using verbal communication and an information folder that is handed out to each participant. Participants are encouraged to ask questions and discuss the issue with the moderator and other group members. At the end of the meeting participants state their WTP individually and anonymously. During the subsequent week-long interval participants are asked to think about the projects and discuss it with their family and friends. They are also encouraged to use the opportunity to gather additional information about the issue.

120 citizens of the municipality of Landau and immediate vicinity were recruited via announcements in the local newspaper and word of mouth. In order to counter sample selection bias, potential participants were not informed of the content of the Market Stall meetings during the recruitment stage. They were merely told that the group discussions were run to assist public project decisions and that each participant would receive a financial incentive worth € 20. Quota sampling was used with quotas on age, gender and membership in an environmental group. According to Harrison and Lesley (1996) this approach is particularly useful for small sample sizes in terms of representativeness. Of the 120 citizens recruited 109 showed up, giving a response rate of 91%. Seven Market Stall meetings were

run with 10-20 participants between December 2005 and January 2006. In total, 96 participants completed the second WTP elicitation round over the phone.

4.2 Results

About 71% supported the idea of butterfly conservation through projects, 6% were against it, and 24% unsure. Prior to estimating mean WTP for each project size responses that may not reflect genuine valuations were identified and eliminated from the data base. These included three strategic bids (participants calculated a fair amount that everybody should pay), three protest bids (participants thought that the state should pay) and two bids that were characterized by embedding (participants valued all wildlife instead of just *M. teleius*).

WTP bids elicited after the week-long interval (Round 2) were used to calculate mean estimates for each project level. These bids are expected to be better considered and more informed since respondents had several days to think about and discuss their preferences and income constraint. This is supported by regression results and existing literature (MacMillan, *et al*. 2002; Whittington, *et al*., 1992).

Table 2 reports mean values and descriptive statistics for the three project levels (cf. Table 1). The calculations include the highest bid on the payment card that respondents were definitely willing to pay. The nature of the payment card is such that it restricts respondents to a certain range of bids; thus, people who hold very high values for *M. teleius* are constrained to the highest bid provided. Hence, this approach provides decision- and policy-makers with 'conservative' estimates as mean WTP tends to be underestimated.

Table 2: Descriptive statistics for WTP (in €)

	Project 1	**Project 2**	**Project 3**
N	88	88	88
Mean	13.45	15.40	22.06
Median	4.00	11.00	12.00
Std. deviation	22.33	23.01	30.55
Range	0-160	0-160	0-160
Confidence interval	8.72-18.19	10.52-20.27	15.59-28.53

A feasible and popular way to test the validity of WTP stated by individuals is to investigate how well WTP estimates are explained by theoretical expectations. The test regresses value estimates against independent variables that are expected to be determinants of WTP. Results from multiple linear regression analyses provide evidence that WTP for each conservation level can be satisfactorily explained by socio-economic and attitudinal variables. The variables selected for inclusion in the regression model as well as the regression results are presented in Appendix 1.

To estimate aggregated economic benefits from *M. teleius* conservation we multiply the mean annual benefit per household with the number of households (19,310) in the municipality of Landau[1]. Table 3 shows the aggregated benefits associated with the three project levels.

Table 3: Aggregated economic benefits for each project level per year

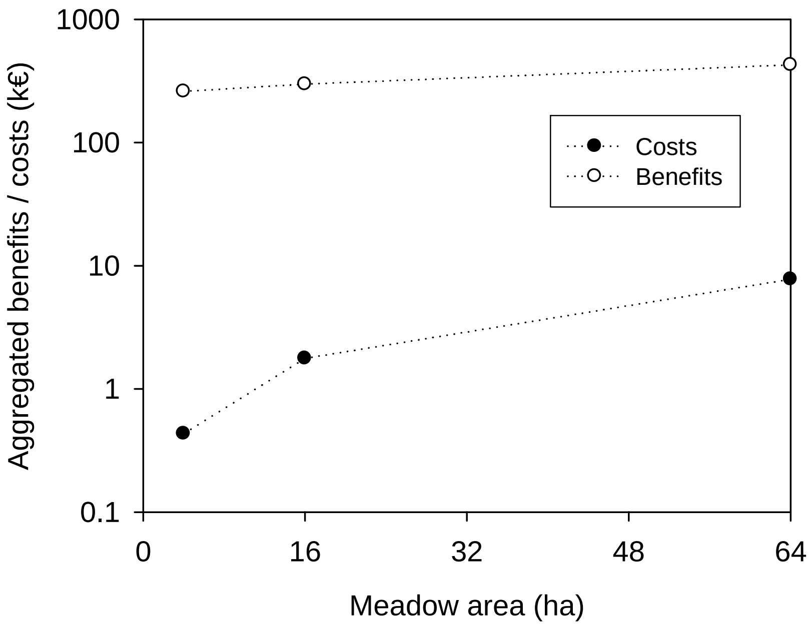
Project level 1	**Project level 2**	**Project level 3**
€ 259 720	€ 297 374	€ 425 979

5. Estimating the optimal level of conservation

To identify the optimal level of conservation, we finally need to bring together the supply (Fig. 2) and demand (Table 3) side. Figure 3 shows that the aggregated benefits are much higher than the aggregated costs (by about three orders of magnitude for project 1 (meadow area of 4 ha) and more than one order of magnitude for project 3 (64 ha of meadows)).

[1] Since no information was available on household numbers, it was decided to divide the population number by the average household size. Information on this was obtained from the Statistical Authorities of Rhineland-Palatinate.

Figure 3: Aggregated benefits and costs in logarithmic scale as a function of project size (meadow area).

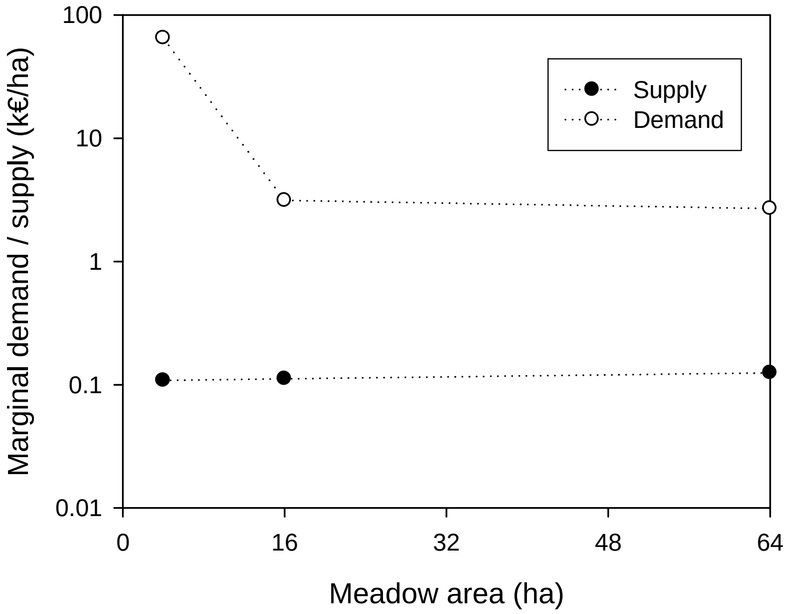


To derive the optimal level of butterfly conservation we have to compare marginal costs and benefits, i.e., the supply and demand curves which are given by the first derivatives of the aggregated values of Fig. 3. Denoting the size and the aggregated benefits of project level *i* (*i*=1,2,3) as A_i and D_i, respectively, we approximate the marginal benefits of project level *i* by

$$d_1 = \frac{D_1}{A_1} \quad \text{and} \quad d_i = \frac{D_i - D_{i-1}}{A_i - A_{i-1}} \quad \text{for} \;\; i = 2,3$$

which is the slope of the line connecting project levels *i*-1 and *i* in Fig. 3. Marginal costs are approximated accordingly (Fig. 4).

Figure 4: Demand and supply in logarithmic scale as a function of project size (meadow area).



One can see that the supply curve is fairly constant (with a slight increase) and around 123 €/ha. Marginal benefits are about 65,000€/ha for project 1; somewhere between project level 1 and 2 they drop to a value of around 3,000€/ha, and from there remain fairly constant (with a slight decrease) up to project level 3. Marginal demand exceeds marginal supply by more than an order of magnitude in the entire range of proposed conservation projects and hence the highest proposed level of butterfly conservation (64 ha of meadow area) is optimal.

6. Discussion

From an economic point of view, determining the optimal level of conservation is conceptually straightforward. There need to be, however, empirical studies that estimate the optimal level of conservation if economists aim at contributing to the discussion on how much conservation a society should aim at. Currently, there are only a few studies addressing the question of optimal conservation and – to our knowledge – none of them looks at conservation problems where costs and benefits of conservation measures are heterogeneous. Our aim is to contribute to filling this gap and we present a study (= estimating the optimal level of conservation for the Scarce Large Blue in the region of Landau, Germany) where costs and benefits of the conservation measure (= mowing meadows) differ in space and over time. Although our case study results are specific to the area and species studied, the methodology is generally applicable to estimate how many financial resources should be allocated to conserve an endangered species in the context of agri-environmental schemes when costs and benefits are heterogeneous.

Why is it important to take into account heterogeneous costs and benefits when estimating the optimal level of conservation? The reason is that if costs and benefits are heterogeneous and this is ignored in the estimation of the supply curve the optimal level of conservation might be underestimated. Consider for purpose of illustration the research by Ando *et al*. (1998) who compare the cost-effectiveness of a purely ecological reserve site selection approach with an approach that takes into account heterogeneous land prices in the selection of reserves. They find that the latter approach may lead to cost savings of up to 90% which implies that a supply curve derived from this approach would be substantially below a supply curve that ignores heterogeneous conservation costs. If an interior solution exists and the demand and supply curve have the usual shape a lower supply curve implies a higher optimal level of conservation.

Estimating heterogeneous marginal costs and benefits of conservation is a complex issue which requires input from economics and ecology. Ecological knowledge is needed because estimating the supply curve requires the identification of cost-effective conservation measures and, hence, information about the spatially and temporally differentiated impacts of measures on the conservation target. However, combining ecological and economic knowledge is not trivial as, e.g., ecologists and economists address issues of scale, time and space in a different way. A particular challenge in the context of estimating the optimal level of conservation is to translate the ecological scientific information required for the supply side into an easy-to-understand language for estimating the public's willingness-to-pay for conservation. In our case study, this required the translation of the ecological-economic modelling approach's scientific description for conservation success – size of the area in hectares occupied by butterflies – into terms which are understood by the public – visibility of the butterfly and reduction of extinction risk (cf. Table 1). As in most type of integrated research good communication between disciplines is essential in solving this challenge (cf. Wätzold *et al*., 2006).

For the estimation of the demand for butterfly conservation the general publics' understanding of the conservation problem is essential. Hence we spent a lot of effort to generate communication that maximizes understanding of respondents with a wide range of different background knowledge and cognitive skills. Given that people are unfamiliar with *M. teleius* and the complexity of the three different conservation projects to be valued, the MS approach was considered to be particularly useful. The method gives participants sufficient information, time to think and the opportunity to discuss the conservation projects. The unusually high response rate to the WTP question (all apart from two participants successfully completed the payment card) suggests that MS tailors scientific information to suit participants with different needs and helps them to successfully tackle the valuation task.

Regarding policy-making we do not argue that decisions about conservation in agricultural landscapes should be solely based on the criterion of economic optimality but may also include considerations such as intra- and intergenerational fairness. However, we believe that it is important that marginal costs and benefits are known to the regulator when decisions concerning conservation are made. Our results convincingly argue that the highest level of butterfly conservation considered is the optimal solution. This result is quite robust. Costs for conservation measures are low and we made conservative assumptions regarding the estimation of the benefit function. Even under this assumption the marginal benefits of conservation exceed the marginal costs by a factor of approximately 25. To our knowledge no conservation measures for *M. teleius* exist in the region indicating a sub-optimal situation characterised by too little conservation. This result is in line with other studies on costs and benefits of conservation (e.g., MacMillan *et al.*, 2004; Siikamäki and Layton, 2005) which also find that a higher than the existing level of conservation is optimal from an economic point of view.

Although no *M. teleius* specific programme exists in Landau farmers can participate in an agri-environmental programme directed at meadow bird conservation. This programme demands from farmers that they do not cut their meadows before the 15 June which is good for meadow birds but detrimental for *M. teleius*. The observation that agri-environmental programmes are directed at certain species but neglect others seems to be a common problem of programmes directed at conservation in Germany (cf. Reiter *et al.*, 2004) and Europe (cf. Benton et al. 2003), and is therefore interesting from a general agricultural policy perspective. As a response to this problem, there has been a demand for habitat heterogeneity in agricultural landscapes because as Benton *et al.* succinctly put it: „if the environment is sufficiently heterogeneous (…), different taxa will find their own habitats“ (Benton *et al.* 2003: 187). Habitat heterogeneity has a further advantage: Insufficient knowledge about the effects of conservation measures on species lead to the risk that conservation programmes fail to create suitable habitats for species (e.g. Kleijn *et al.*, 2001). If a variety of habitats exist this risk decreases.

Compared to our research estimating the optimal level of conservation in terms of habitat heterogeneity poses several additional challenges which future research may address: On the demand side, it is obviously easier to estimate the willingness-to-pay for a concrete species than for a rather abstract concept such as habitat heterogeneity. The advantages of habitat heterogeneity need to be clearly outlined and explained to people so that they are able to adequately value the idea. While conventional survey methods may not be capable of conveying comprehensive information, the MS approach has been successfully applied to value complex environmental goods and services (Lienhoop and MacMillan, 2006). Regarding the supply side, it is important to note that different farmers have to carry out different conservation measures to generate habitat heterogeneity. This implies that the cost-effective allocation of conservation measures among farmers has to be identified, and, in addition, that a co-ordination problem has to be solved that arises when different farmers shall carry out different measures on a voluntary basis. Ohl *et al*. (2006) have shown that an intuitive solution – the differentiation of compensation payments in space and/or over time – may not always be possible. The reason is that depending on the farmers' cost function it may be impossible to differentiate payments in a way that the farmers do not opt for only one or a few but for all conservation measures. This implies that policy alternatives have to be considered. An example is an agglomeration bonus where farmers only receive a payment when the conservation measures in a region are carried out in a certain spatial configuration (Parkhurst *et al*., 2002). Estimating the costs of a policy instrument which requires co-ordination among farmers is challenging because additional transaction costs arise which may be difficult to estimate.

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Appendix 1:

Coding and mean values for independent variables used in regression model

Variable	Coding	Mean
PRIORITY (priority for government expenditure on environment)	1= highest priority to 6= lowest priority	3.52
INCOME (annual household income after tax)	1= less than € 500 to 6= more than € 4000	3.05
IMPORTANCE (whether people feel that their WTP reflects the perceived importance they have for the project)	1= strong influence 4= no influence	2.53
KNOWLEDGE (change in knowledge due to MS meeting)	1= not at all to 4= very much	2.73

Regression estimates for all Project levels.

	Project 1		**Project 2**		**Project 3**	
R^2	0.125		0.141		0.242	
F	2.778		3.271		6.292	
Sig.	0.033		0.015		0.001	
	T	**Sig.**	***T***	**Sig.**	***T***	**Sig.**
Constant	-0.432	0.667	0.136	0.892	0.038	0.970
PRIORITY	-0.426	0.671	-0.780	0.437	-1.085	0.281
INCOME	-1.469	0.146	1.444	0.153	2.239	0.028
IMPORTANCE	-0.840	0.403	-1.444	0.153	-2.174	0.033
KNOWLEDGE	1.982	0.051	1.919	0.059*	2.412	0.018